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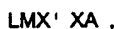
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(54) Homogeneous olefin polymerization catalyst by ligand abstraction with lewis acids.

(57) Addition polymerization catalysts having a limiting charge separated structure corresponding to the formula :



wherein :

L is a derivative of a substituted delocalized π -bonded group imparting a constrained geometry to the metal active site and containing up to 50 nonhydrogen atoms ;

M is a metal of Group 4 or the Lanthanide series of the Periodic Table of the Elements ;

X independently each occurrence is hydride or a hydrocarbyl, silyl or germyl group having up to 20 carbon, silicon or germanium atoms ; and

A^- is an anion of a Lewis acid, A, having relative Lewis acidity greater than or equal to that of phenylbis(perfluorophenyl)borane, said anion being compatible with the metal cation, are prepared by contacting a derivative of a Group 4 or Lanthanide metal corresponding to the formula :



wherein

L, M, and X are as previously defined,
with the Lewis acid, A.

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of the substituted delocalized Π -bonded group need not be equivalent. That is, the metal may be symmetrically or unsymmetrically Π -bound to the substituted delocalized Π -bonded group.

The geometry of the active metal site is further defined as follows. The center of the substituted delocalized Π -bonded group may be defined as the average of the respective X, Y, and Z coordinates of the atomic centers forming the substituted delocalized Π -bonded group. The angle, Θ , formed at the metal center between the center of the ligating atom of each other ligand of the metal complex may be easily calculated by standard techniques of single crystal X-ray diffraction. Each of these angles may increase or decrease depending on the molecular structure of the constrained geometry metal complex. Those complexes wherein one or more of the angles, Θ , is less than in a similar, comparative complex differing only in the fact that the constrain-inducing substituent is replaced by hydrogen have constrained geometry for purposes of the present invention. Preferably one or more of the above angles, Θ , decrease by at least 5 percent, more preferably 7.5 percent, compared to the comparative complex. Highly preferably, the average value of all bond angles, Θ , is also less than in the comparative complex.

Preferably, metal coordination complexes of Group 4 or Lanthanide metals according to the present invention have constrained geometry such that the smallest angle, Θ , is less than 115° , more preferably less than 110° , most preferably less than 105° .

Substituted delocalized Π -bonded groups for use herein include any Π -electron containing moiety capable of forming a delocalized bond with the Group 4 or Lanthanide metal and further substituted with one or more divalent substituents that are also covalently bound to the metal. Divalent substituents preferably include groups containing up to 30 nonhydrogen atoms comprising at least one atom that is oxygen, sulfur, boron or a member of Group 14 of the Periodic Table of the Elements directly attached to the delocalized Π -bonded group, and a different atom, selected from nitrogen, phosphorus, oxygen and sulfur that is covalently bonded to M. Examples of suitable delocalized, Π -bonded groups are cyclopentadienyl- or allyl-groups, and derivatives thereof.

By the term "derivative" in the definition of L is meant that each atom in the delocalized Π -bonded group may independently be substituted with a radical selected from hydrocarbyl radicals, substituted-hydrocarbyl radicals wherein one or more hydrogen atoms are replaced by a halogen atom, hydrocarbyl-substituted metalloid radicals wherein the metalloid is selected from Group 14 of the Periodic Table of the Elements, and halogen radicals. Suitable hydrocarbyl and substituted-hydrocarbyl radicals used to form derivatives of the delocalized Π -bonded group contain from 1 to 20 carbon atoms and include straight and branched alkyl radicals, cyclic hydrocarbon radicals, alkyl-substituted cyclic hydrocarbon radicals, aromatic radicals and alkyl-substituted aromatic radicals. In addition two or more such radicals may together form a fused ring system or a hydrogenated fused ring system. Examples of the latter are indenyl-, tetrahydroindenyl-, fluorenyl-, and octahydrofluorenyl- groups. Suitable hydrocarbyl-substituted organometalloid radicals include mono-, di- and trisubstituted organometalloid radicals of Group 14 elements wherein each of the hydrocarbyl groups contains from 1 to 20 carbon atoms. More particularly, suitable hydrocarbyl-substituted organometalloid radicals include trimethylsilyl, triethylsilyl, ethyldimethylsilyl, methyl-diethylsilyl, triphenylgermyl, and trimethylgermyl.

Preferably M is a metal of Group 4 of the Periodic Table of the Elements, most preferably titanium or zirconium. Also, preferably X is C_1 - C_{10} hydrocarbyl, most preferably benzyl and especially methyl.

Highly preferred Group 4 or Lanthanide metal derivatives are substituted monocyclopentadienyl compounds corresponding to the formula:



wherein:

M is titanium or zirconium;

Cp is a cyclopentadienyl group or derivative thereof that is Π -bound to M and substituted at least by Z;

Z is a divalent moiety comprising oxygen, sulfur, boron, or a member of Group 14 of the Periodic Table of the Elements;

Y is a ligand group comprising nitrogen, phosphorus, oxygen or sulfur or optionally Z and Y together form a fused ring system; and

X is as previously defined.

After abstraction of the X group, the highly preferred catalysts of the invention have a limiting, electron separated structure corresponding to the formula:

containing other Group 4 or Lanthanide metals, will, of course, be apparent to those skilled in the art.

Suitable anions are those that either do not coordinate to or are only weakly coordinated to said metal cation, thereby remaining sufficiently labile to be displaced by a neutral Lewis base. A "compatible" anion additionally refers to such an anion that, when functioning as a charge balancing anion in the catalyst system of this invention, within the time frame of the desired end use, does not transfer an anionic substituent or fragment thereof to the cation thereby forming a neutral metallocene and a neutral metal byproduct. In addition such anions are not degraded to neutrality when the initially formed complex decomposes and are noninterfering with desired subsequent polymerizations or other uses of the complex.

The Lewis acids having Lewis acidity suitable for use according to the present invention are prepared according to known techniques such as those of Marks, et al. *J. Am. Chem. Soc.* 1991, 113, 3623-3625, or J. Pohlman, et al., *Naturforschg.* 1965, 20b, 5-11. The preferred technique is to combine a boron or aluminum halide compound such as boron trichloride or boron trifluoride with an alkali metal or alkaline earth derivative of the desired substituent or substituents. Additionally, borate esters such as tris(perfluorophenyl) borate may be prepared by the reaction of pentafluorophenylphenol and borane-methyl sulfide complex according to the method of *J. Org. Chem.*, 43(13) 2731-32 (1978).

Lewis acidity may be measured by empirical means and may also be predicted with a high degree of certainty based on theoretical methods. A preferred technique for measuring Lewis acidity is the proton NMR chemical shift of the proton on carbon #3 (H-3) of crotonaldehyde complexes of the Lewis acid. This technique was disclosed by R. Childs et al., *Can. J. Chem.*, 1982, 802-808. A similar technique for determining Lewis acidity was taught in P. Laslo et al. *J. Am. Chem. Soc.* 1990, 112, 8750-8754. The units of measurement are $\Delta\delta$ (ppm). It has been discovered that the technique may be practiced at temperatures at or less than 25°C without deleterious effect.

The difference in chemical shift of the 3-hydrogen of free, uncomplexed crotonaldehyde and the 3-hydrogen of the complexed Lewis acid adduct is determined. This chemical shift difference ($\Delta\delta$ in ppm) is related to the Lewis acidity of the species under study, with the trend being the more downfield the 3-hydrogen is shifted, the greater the Lewis acidity of the compound being examined. The chemical shift difference of phenylbis(perfluorophenyl)borane is 0.77 ppm. More Lewis acidic compounds have chemical shift differences, $\Delta\delta$, more than 0.77. Preferred Lewis acids have an acidity from 0.77 to 1.49, more preferably from 1.0 to 1.49. Thus, by the Childs et al. technique, useful Lewis acids for the present invention are acids having relative acidity compared to phenylbis(perfluorophenyl)borane, $\Delta\delta' - \Delta\delta^\circ \geq 0$ (where $\Delta\delta'$ is the Lewis acidity of the candidate Lewis acid and $\Delta\delta^\circ$ is the Lewis acidity of phenylbis(perfluorophenyl)borane). Preferred Lewis acids are those having relative acidity from 0 to 0.72, more preferably from 0.23 to 0.72.

Detrimental reactivity of Lewis acids includes abstraction of one or more groups from the anion by the cationic portion of the catalyst, LMX⁺. Readily extractable groups comprise the halides when such halide is directly attached to a central Group 13 metalloid. Thus, most preferred non-reactive Lewis acids are Lewis acids that are devoid of halide groups directly attached to a central Group 13 metalloid, especially boron. Stated otherwise, most preferred Lewis acids are boron compounds devoid of halogen moieties directly attached to the boron.

Theoretical techniques may also be utilized to calculate the acidity of Lewis acids suitable for use according to the present invention. Several commercially available computer programs may be used to calculate the Lewis acidity. In a preferred technique theoretical structures and total energies may be calculated for candidate molecules in a proposed reaction of a Lewis acid with a Lewis base to form a complex. Molecules giving larger calculated heats of complexation indicate greater Lewis acidity. A program such as GAUSSIAN 90, or similar molecular simulation software may be used for the simulation and analysis of such materials.

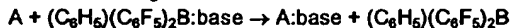
First, the initial structures are optimized by minimizing the calculated total energy with respect to all degrees of freedom: bond lengths, bond angles, and torsional angles. The heat of reaction (ΔH) is then calculated as being the difference between the total energy of the products and the total energy of the reactants e.g.,

$$\sum E_{(\text{products})} - \sum E_{(\text{reactants})}$$

where

E is approximated by the quantum mechanical energy (E_{QM}) at absolute zero temperature (0° Kelvin) for reactants and products.

By the foregoing technique the Lewis acidity of a compound towards a Lewis base such as methyl anion (CH_3^-) or ammonia can be calculated, using the formula:



where A is the Lewis acid and "base" is the Lewis base. If the reaction is exothermic ($\Delta H < 0$), then A is a stronger Lewis acid than phenylbis(perfluorophenyl)boron. Relative acidity is determined by comparison to the calculated ΔH of phenylbis(perfluorophenyl)boron, which by definition is 0.0 kcal/mole.

Based on the foregoing empirical and theoretical techniques highly preferred Lewis acids are: tris(pentafluorophenyl)borane, tris (2,3,5,6-tetrafluorophenyl)borane, tris(2,3,4,5-tetrafluorophenyl)borane,

of polymer produced/catalyst weight) are at least five times greater than that obtained with comparable alumoxane containing catalysts.

In general, catalysts can be selected so as to produce polymer products which will be relatively free of large amounts of certain trace impurities such as aluminum, magnesium and chloride generally found in polymers produced with Ziegler-Natta type catalysts. The polymer products produced with the catalysts of this invention have a broader range of applications than polymers produced with more conventional Ziegler-Natta type catalysts comprising a halogenated metal alkyl such as magnesium chloride, or an alkyl aluminum chloride.

Having described the invention the following examples are provided as further illustration thereof and are not to be construed as limiting. Unless stated to the contrary all parts and percentages are expressed on a weight basis.

General Polymerization Procedure

Ethylene, propylene, and hydrogen were purified by passing through columns of 13X molecular sieve, activated alumina, and trace oxygen removal catalyst (alumina supported copper/manganese catalyst available from Engihardt Inc. under the tradename Q-5). Solvents and octene were degassed with nitrogen, then were purified by passing through columns of 13X molecular sieve, activated alumina, and trace oxygen removal catalyst. Phenylacetylene-free styrene was degassed with nitrogen, then purified by passing through a column of activated alumina. A 2 L stirred autoclave was charged with the desired amounts of a solvent and comonomer.

Hydrogen was added by differential pressure expansion from a 75 mL addition tank. The hydrogen pressure differential represents the difference in pressure between the starting and final pressure in the hydrogen addition tank after adding hydrogen to the 2L reactor containing solvent and comonomer. The reactor was heated to the polymerization temperature and was saturated with ethylene to the desired pressure. Metal complex and Lewis acid cocatalyst were mixed in a drybox by syringing the desired amount of 0.0050 M metal complex solution (in mixed alkane solvent (Isopar E™ available from Exxon Chemicals Inc.) or toluene) into a solution of the cocatalyst (in Isopar® E or toluene solvent). Optionally, additional solvent was added to facilitate transfer of the catalyst solution to the reactor. This solution was then transferred to a catalyst addition tank and injected into the reactor.

The polymerization was allowed to proceed for the desired time and then the solution was drained from the bottom of the reactor and quenched with isopropanol. A hindered phenolic antioxidant (Irganox® 1010, available from Ciba-Geigy Corporation) was added and the polymer was air dried overnight. The residual solvent was removed in a vacuum oven overnight.

Polymer melt indices (I2) were measured according to ASTM D-1238, Procedure A, Condition E, using a micro-melt indexer, Model CS-127MF, available from Custom Scientific Instruments, Inc. Densities are determined by buoyancy measurements of compression molded samples in methyl ethyl ketone.

Experimental Determination of Lewis acidity

The Lewis acidity of phenylbis(perfluorophenyl)borane was determined using NMR analysis substantially according to the technique of R. Childs, et al., *Can. J. Chem.*, 1982, 60, 802-808. All manipulations were carried out either using standard Schlenk and/or high vacuum techniques or in an inert glovebox (Vacuum Atmospheres, Inc.) under recirculating, dry nitrogen with oxygen levels in the glove box being continuously monitored with an oxygen analyzer and maintained at < 1ppm. Crotonaldehyde purified by vacuum-transfer from calcium hydride and methylene chloride-d₂ (CD₂Cl₂) vacuum transferred from phosphorus pentoxide were used.

Proton NMR spectra were recorded either on a Varian VXR-300 NMR spectrometer or a Varian Gemini 300 NMR spectrometer. Chemical shifts were determined relative to tetramethylsilane through the residual CHDCl₂ (¹H, δ 5.32) in CD₂Cl₂. The NMR samples were prepared by adding an appropriate quantity of the Lewis acid compound to a solution of crotonaldehyde in CD₂Cl₂ at -20°C and allowing the sample to warm slowly to room temperature. The stoichiometry of the resulting solution was such that there was a 50 percent excess of the Lewis acid reagent with a total concentration of reactants being about 0.3M. The ¹H NMR spectrum was then recorded, and H-3 NMR shift of the Lewis acid adduct of crotonaldehyde and free crotonaldehyde determined.

Theoretical calculation of Lewis acidity

Structures and energies were calculated using one or more of the following standard techniques of electronic structure theory.

1. AMI - Dewar's semi-empirical method based on approximate molecular orbital theory. AMI has been par-

Examples 3-37

The metal complex for Examples 3-37 was (tert-butylamido)dimethyl(tetramethyl-5-cyclopentadienyl)silane titanium dimethyl, $[(C_6Me_4)SiMe_2N(t-Bu)]TiMe_2$, and the Lewis acid was tris(perfluorophenyl)borane, $B(C_6F_5)_3$. The polymerization time for all examples was 10 minutes. The results for Examples 3-37 are shown in Table I.

Table I

Ex	T(°C)	$H_2 \Delta kPa$	$C_2H_4 MPa$	1-octene (mL)	Lewis acid (μ Mole)	Ti (μ Moles)	Yield, g	MI (I2)	Density, g/mL
3	204	300	3.45	0	15	10.00	15.1	37.9	-
4	190	340	3.45	0	9	6.00	18.7	27.54	-
5	190	0	3.45	0	9	6.00	6.3	0.04	-
6	190	170	3.45	0	9	6.00	25.8	5.5	-
7	176	300	3.45	0	6	4.00	30.2	10.6	-
8	210	170	3.45	0	15	10.00	8.6	21.23	-
9	190	170	3.45	0	9	6.00	14	5.23	-
10	204	50	3.45	0	15	10.00	7.1	1.6	-
11	170	170	3.45	0	6	4.00	40.6	1.99	-
12	190	170	3.45	0	9	6.00	17.1	3.54	-
13	190	170	3.45	0	9	6.00	16.7	5.34	-
14	176	50	3.45	0	6	4.00	26.2	0.2	-
15	190	170	3.45	0	9	6.00	20.4	4.34	-
16	170	0	3.45	0	6	4.00	28	0.04	-
17	210	0	3.45	0	15	10.00	1.1	-	-
18	163	340	3.28	55	1.25	1.25	22.4	3.54	0.9220
19	163	170	3.28	55	1.25	1.25	45.5	1.04	0.9173
20	150	170	3.28	55	1.25	1.25	77.3	1.35	0.9115

merization. The reaction was allowed to proceed for 15 minutes with ethylene being supplied on demand at 475 psig (3.38 MPa). The propylene content of the polymer was determined by carbon NMR spectroscopy using the method of J.C. Randall, *Rev. Macromo. Chem. Phys.*, 29(2&3), 201-317, (1989). The results are shown in Table II.

Table II

Ex	Propene (g)	Temp (°C)	H ₂ ΔkPa	Ti (μmol)	Yield, g	Melt Index (I ₂)	Propylene Mol%	Density, (g/mL)
38	100	95	690	.500	70.9	3.551	30.7	0.8520
39	86	550	550	.375	109.0	0.671	40.0	0.8513
40	130	86	140	.325	98.1	0.184	41.2	0.8522
41	100	95	0	.325	71.7	0.063	31.9	0.8516
42	130	104	550	.750	99.5	6.984	50.2	0.8514
43	100	95	340	.375	92.8	0.956	46.0	0.8518
44	100	95	340	.375	88.7	0.777	38.0	0.8516
45	50	95	340	.375	79.1	0.372	24.2	0.8631
46	70	86	550	.375	94.7	1.098	30.0	0.8544
47	100	80	340	.300	96.8	0.261	34.3	0.8518
48	70	104	550	.500	75.6	2.122	30.0	0.8540
49	100	110	340	.750	91.6	4.093	38.2	0.8536
50	100	95	340	.500	96.5	1.203	38.1	0.8501
51	70	86	140	.250	72.8	0.000	28.2	0.8559
52	100	95	340	.325	79.2	0.796	35.8	0.8491
53	100	95	340	.325	82.3	0.674	37.5	0.8518
54	70	104	140	.750	92.6	0.830	32.9	0.8533
55	100	95	340	.325	82.5	0.733	35.2	0.8517
56	130	104	140	.500	84.1	1.697	43.2	0.8497
57	100	95	340	.325	83.1	0.503	36.8	0.8508

Examples 59 - 77

The procedure of Examples 3 - 37 was followed except that various amounts of styrene were added to the reactor followed by Isopar® E to make 1000 mL of total liquid volume. Various amounts of propylene were then added. The solution was heated to the reaction temperature. The solution is then saturated with ethylene at 480 psig (3.41 MPa). Equimolar amounts of the metal complex, $[(C_6Me_4)SiMe_2N(t-Bu)]TiMe_2$, and the Lewis acid, $B(C_6F_5)_3$ were mixed in 2 mL of Isopar® E and this solution was transferred into the reactor to begin the

Table IV

Ex	Styrene (mL)	Temp (°C)	Hydrogen (kPa)	Catalyst (μ mol)	Yield, g	Melt Index (I2)	Styrene Content (mole %)
78	125	145	0	5.0	24.0	0.209	0.8
79	75	145	76	5.0	44.8	0.436	0.5
80	225	145	76	7.5	37.5	2.117	1.5
81	234	136	110	7.5	59.8	1.884	1.7
82	175	145	69	7.5	52.5	1.471	1.3
83	175	145	"	7.5	52.0	1.352	1.4
84	234	154	28	7.5	34.4	2.447	1.5
85	116	136	110	5.8	65.1	0.739	-
86	275	145	69	7.5	46.2	2.055	1.9
87	175	160	"	7.5	31.1	7.111	1.2
88	175	130	"	3.0	46.3	0.335	-
89	116	154	"	7.5	49.2	4.061	1.0
90	234	154	"	7.5	39.8	9.417	1.6
91	175	145	140	7.5	55.1	3.494	-
92	175	145	69	7.5	53.1	1.144	-
93	116	154	28	7.5	46.4	0.710	0.8
94	175	145	69	7.5	52.6	1.134	1.4
95	234	136	28	5.0	45.5	0.270	-
96	175	145	69	7.5	52.2	1.185	-
97	175	145	0	7.5	50.2	0.465	-
98	175	145	69	7.5	51.3	1.126	-
99	75	145	"	7.5	63.0	0.489	0.6
100	116	136	28	5.0	52.5	0.115	-

Example 101

The polymerization procedure of Examples 3-37 was followed using 1.25 micromoles of (tert-butylamido)dimethyl(tetramethyl- η -5-cyclopentadienyl)silane titanium dibenzyl $[(C_5Me_4)SiMe_2N(t-Bu)]Ti$ bz₂ and 1.25 micromoles of the Lewis acid, B(C₆F₅)₃ mixed in 2 mL of Isopar® E. The reaction temperature was 160°C. 10 g of propylene and 100 Δ psi (0.7 MPa) hydrogen were added. The ethylene pressure was 460 psig (3.3 MPa). The polymerization time was 15 minutes. 22.9 g of an ethylene / propylene copolymer were isolated.

Example 102

The polymerization procedure of Example 101 was followed using 1.00 micromoles of $[(C_5Me_4)SiMe_2N(t-Bu)]TiMe_2$ and 1.00 micromoles of the Lewis acid B(C₆F₅)₃ mixed in 2 mL of Isopar® E. The reaction temperature was 90°C. 1000 mL of Isopar® E and 200 mL of 1-octene were charged into the reactor and no hydrogen was added. The ethylene pressure was 500 psig (3.55 MPa). The polymerization time was 15 minutes. 85.9 g of

Et₂O) was added dropwise with stirring over a 20 min period. Upon completion of the addition of the MeMgI the solution was stirred for 40 minutes. After this time period the Et₂O was removed under reduced pressure and the residue extracted with pentane, the solution filtered and the filtrate evaporated to dryness under reduced pressure to give 3.48 g (77 percent yield) of product.

Polymerization

The polymerization procedure of Example 102 was followed using 2.00 micromoles of [(tetrahydrofluorenyl)SiMe₂N(t-Bu)]TiMe₂ and 2.00 micromoles of the Lewis acid, B(C₆F₅)₃ mixed in 2 mL of Isopar® E. The reaction temperature was 130°C. 808 g of Isopar® E and 100 g of 1-octene are charged into the reactor. No hydrogen was added. The ethylene pressure was 500 psig (3.55 MPa). The polymerization time was 15 minutes. 41.1 g of an ethylene/ octene copolymer were isolated.

Example 104.

The procedure of Example 103 was followed except that 2.50 micromoles of [(tetrahydrofluorenyl)SiMe₂N(t-Bu)]TiMe₂ and 2.50 micromoles of the Lewis acid B(C₆F₅)₃, were mixed in 2 mL of Isopar® E were used to form the catalyst. The reaction temperature was 150°C. 829 g of Isopar® E and 29 g of 1-octene are charged into the reactor and no hydrogen was added. The ethylene pressure was 500 psig (3.55 MPa). The polymerization time was 15 minutes. 11.4 g of an ethylene/ octene copolymer were isolated.

Example 105.

Polymerization using (tert-butylamido)dimethyl(1,3-dimethyl-5,6,7,8-tetrahydroindenyl)silane titanium dimethyl metal derivative

Preparation of 4,5,6,7-tetrahydro-1-methyl-indan-3-one

Cyclohexene (27.3g, 0.33 mol), crotonic acid (28.7g, 0.33mol) and polyphosphoric acid (300ml) were mechanically stirred under a nitrogen atmosphere at 60°C for 30 minutes. The slurry was poured into water and the aqueous solution extracted with diethyl ether. The diethyl ether extract was washed successively with a 10 percent NaHCO₃ solution and a saturated NaCl solution. The organic extract was then dried over anhydrous MgSO₄. The solution was then filtered and the solvent removed under reduced pressure. The crude product was then purified via vacuum distillation (bp 87-92°C at 5 torr, 0.7 kPa) to give 32.6g (66 percent) of purified material.

Preparation of 7,9 dimethylbicyclo-[4.3.0]-nona-l(6),7-diene

Methyl lithium (1.5M, 96ml) was added dropwise to a solution of 4,5,6,7-tetrahydro-1-methyl-indan-3-one (17.7g, 0.118 mol) in 50ml of diethyl ether under an argon atmosphere whereupon the reaction mixture was refluxed for 18 hours. The mixture after this time period was hydrolyzed and the reaction mixture extracted with diethyl ether. The ether extracts were dried over anhydrous MgSO₄ and filtered. To the ether solution, 0.5ml of 6M HCl was added and the solution stirred for one hour. After this time period the ether solution was washed with water, dried over anhydrous MgSO₄, filtered and concentrated. Distillation at reduced pressure afforded 8.0g (45 percent) of product.

Preparation of lithium 1,3-dimethyl-5,6,7,8-tetrahydroindenide

7,9 dimethylbicyclo-[4.3.0]-nona-l(6),7-diene (5.0g, 33.5 mmol) was added to 100ml of pentane. To this solution n-BuLi in pentane (2.7M, 13ml) was added dropwise and the mixture stirred for 12 hours. The resulting white precipitate was collected via filtration, washed with pentane and dried under reduced pressure to give 5.02g (97 percent) of product.

Preparation of (N-t-butylamino)(dimethyl)(1,3-dimethyl-5,6,7,8-tetrahydroindenyl)silane

0.77g of ClSiMe₂NHMe₃ (4.67 mmol) was added to 50 ml of THF. To this solution 0.75g (4.67 mmol) of lithium 1,3-dimethyl-5,6,7,8-tetrahydroindenide was added. The solution was then brought to reflux for 10 min and the solution was then cooled to room temperature. Gas-Chromatogram (GC) analysis showed the reaction

Example 108.

The procedure of Example 107 was followed except that 2.00 micromoles of [(tetrahydrofluorenyl)SiMe₂N(t-Bu)]Tibz₂ (prepared by reacting [(N-t-butylamido)(dimethyl)tetrahydrofluorenyl]silane) titanium dichloride with benzyl magnesium chloride) and 2.00 micromoles of the Lewis acid, B(C₆F₅)₃ mixed in 2 mL of Isopar® E were used to form the catalyst. The reaction temperature was 150°C. 822 g of Isopar® E and 36 g of 1-octene were charged into the reactor and 10 Δpsi (0.07 ΔMPa) of hydrogen was added. The ethylene pressure was 500 psig (3.55 MPa). The polymerization time was 15 minutes. 20.1 g of an ethylene/octene copolymer were isolated. The melt index, I₂, was 0.327.

Example 109.

The procedure of Example 108 was followed except that 2.00 micromoles of [(tetrahydrofluorenyl)SiMe₂N(t-Bu)]Tibz₂ and 2.00 micromoles of the Lewis acid, B(C₆F₅)₃ mixed in 2 mL of Isopar® E were used to form the catalyst. The reaction temperature was 150°C. 822 g of Isopar® E and 36 g of 1-octene are charged into the reactor and 10 Δpsi (0.07 ΔMPa) of hydrogen was added. The ethylene pressure was 500 psig (3.55 MPa). The polymerization time was 15 minutes. 20.1 g of an ethylene/octene copolymer were isolated. The melt index, I₂, was 0.327.

Example 110.

Polymerization using (n-tertbutylamido)dimethyl(η⁵-tertbutylcyclopentadienyl)silane titanium dimethyl metal derivative

Lithium t-butylcyclopentadienide

To a solution of 4.18 g (39.4 mmol) 6,6-dimethylfulvene in 80 mL diethylether at 0°C were added 22.9 mL of a 1.72 M (39.4 mmol) methyl lithium solution in ether. The resulting slurry was stirred several days, then filtered, washed with pentane and dried under vacuum.

(N-t-butylamino)(dimethyl)(t-butylcyclopentadienyl)silane

To a solution of 3.35 g (20.2 mmol) (N-t-butylamino)(chloro)dimethylsilane in 75 mL THF was added 3.58 g (17.7 mmol) lithium t-butylcyclopentadienide etherate. The reaction mixture was stirred several hours. The solvent was removed, the residue was extracted with pentane and filtered. The pentane was removed in vacuo to give the product as a pale yellow oil. The yield was 2.87 g, 64.6 percent.

Dilithium[(N-t-butylamido)(dimethyl)(t-butylcyclopentadienyl)silane]

To a solution of 2.87 g (11.4 mmol) (N-t-butylamino)(dimethyl)(t-butylcyclopentadienyl)silane in 70 mL ether was added 15.8 mL of 1.48 M (23.4 mmol) butyl lithium in hexane. The resulting clear solution was stirred overnight. The solvent was removed under reduced pressure. Yield was 107 percent of impure product.

[(N-t-butylamido)(dimethyl)(η⁵-t-butylcyclopentadienyl)silane]titanium dichloride [(t-butyl-C₆H₃)SiMe₂N(t-Bu)]TiCl₂

In a flask were combined 0.60 g (2.27 mmol) dilithium[(N-t-butylamido)(dimethyl)(t-butylcyclopentadienyl)silane] and 0.84 g (2.27 mmol) TiCl₃(THF)₃ as solids. To this was added 40 mL THF. The resulting dark violet solution was stirred for 10 minutes, then 0.35 g (1.25 mmol) PbCl₂ was added. The reaction mixture was stirred for less than one hour, the deep orange-brown reaction mixture was filtered, and the solvent removed under reduced pressure. The residue was extracted with pentane and the solution filtered and concentrated until solid material began to form. The slurry was cooled overnight in a freezer, the yellow product was collected on a frit, washed with pentane and dried under reduced pressure. The yield was 0.58 g, 69.6 percent.

[(N-t-butylamido)(dimethyl)(η⁵-t-butylcyclopentadienyl)silane]titanium dimethyl [(t-butyl-C₆H₃)SiMe₂N(t-Bu)]Ti(CH₃)₂

A 0.80 mL solution of 2.78 M (2.22 mmol) methyl magnesium iodide in 15 mL ether was slowly added over

filtered, the solid extracted with three 20 mL portions of mixed hexane solvent and the filtrate was reduced to 20 mL under reduced pressure. The resulting solution was cooled to -78°C, giving a very thick slurry of colorless, crystalline solid. The slurry was thinned by addition of 20 mL of hexane. The solid was collected by filtration and dried under reduced pressure. Yield was 4.86g, 57 percent.

Polymerization

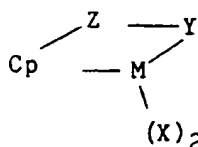
The polymerization procedure of Examples 3 - 37 was followed except that 850 mL of Isopar® E is added to the reactor followed by 20 g of propylene. 25 Δpsi (0.17 ΔMPa) of hydrogen were then added and the solution heated to 130°C. The solution was then saturated with ethylene at 500 psig (3.55 MPa). 10 micromoles of the metal complex $[(C_5Me_4)SiMe_2N(t-Bu)]TiMe_2$ and 10 micromoles of the Lewis acid, $B(C_6F_5)_2(C_6H_5)$, were mixed in 2 mL of Isopar® E and this solution was transferred into the reactor to begin the polymerization. The reaction was allowed to proceed for 15 minutes with ethylene being supplied on demand at 500 psig (3.55 MPa). 2.8 g of an ethylene/ propylene copolymer were obtained. The melt index, I_2 , was 7.52.

Example 115 Ethylene / ethylenenorbornene copolymer

The procedure of Example 111 was followed using two consecutive additions of a catalyst solution prepared by mixing 5.0 micromoles of $[C_5Me_4)SiMe_2N(t-Bu)]TiMe_2$ and 5.0 micromoles of the Lewis acid, $B(C_6F_5)_3$, mixed in 2 mL of Isopar® E. The reaction temperature was 130°C. 1200 mL of a solution containing 50 mL of 5-ethy-
lidene-2-norbornene in Isopar® E and 50 psi (0.34 ΔMPa) hydrogen were added. The ethylene pressure was 475 psig (3.38 MPa). The polymerization time was 20 minutes. 59.9 g of an ethylene / 5-ethy1idene-2-norbornene copolymer was isolated. The melt index, I_2 , was 1.55. The polymer contains 9.06 weight percent 5-ethy-
lidene-2-norbenene as determined by ^{13}C NMR.

Example 116

Various Lewis acids are tested for Lewis acidity for use in preparation of catalysts according to the present invention. Acidity values and the techniques employed in determining such values are contained in Table V.



wherein:

M is titanium or zirconium;

Cp is a substituted cyclopentadienyl group or derivative thereof that is Π -bound to M and substituted at least by Z;

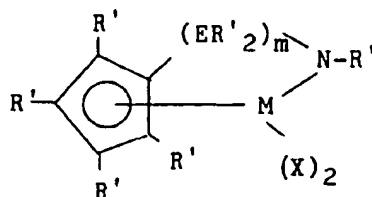
Z is a divalent moiety comprising oxygen, sulfur, boron, or a member of Group 14 of the Periodic Table of the Elements;

Y is a ligand group comprising nitrogen, phosphorus, oxygen or sulfur or optionally Z and Y together form a fused ring system; and

X is as previously defined in claim 1.

4. A process as claimed in Claim 3, wherein -Z-Y- is an amidosilane or amidoalkane group.

5. A process as claimed in Claim 4, wherein LMX_2 corresponds to the formula:



wherein:

M is titanium or zirconium, bound to an η^5 -cyclopentadienyl group;

R' each occurrence is independently selected from hydrogen, silyl, alkyl, aryl and combinations thereof having up to 20 carbon or silicon atoms, and optionally two or more R' groups on the cyclopentadienyl group may form a fused ring system;

E is silicon or carbon;

X independently each occurrence is hydride, alkyl, aryl or halogen substituted aryl of up to 20 carbons; and

m is 1 or 2.

6. A process as claimed in Claim 5, wherein $-(ER'_2)_m-NR'$ has up to 20 nonhydrogen atoms.

7. A process as claimed in Claim 6, wherein $-(ER'_2)_m-NR'$ is (tert-butyl)(dimethylsilyl) or (tert-butyl)-1-ethan-2-yl.

8. A process as claimed in any one of the preceding claims, wherein X is hydride or C_1 - C_{10} hydrocarbyl.

9. A process as claimed in Claim 8, wherein X is methyl or benzyl.

10. A process as claimed in Claim 9, wherein R' each occurrence in the cyclopentadienyl group is hydrogen or C_1 - C_4 alkyl and optionally two or more of said R' together with the cyclopentadienyl group form a tetrahydroindenyl or tetrahydrofluorenyl group, and R' on the nitrogen atom is tert-butyl.

11. A process as claimed in any one of the preceding claims wherein the Lewis acid is a boron compound lacking in halogen moieties directly attached to the boron.

12. A process as claimed in any one of the preceding claims, wherein the Lewis acid is selected from tris(pentafluorophenyl)borane, tris(2,3,5,6-tetrafluorophenyl)borane, tris(2,3,4,5-tetrafluorophenyl)borane, tris(3,4,5-trifluorophenyl)borane, tris(1,2,2-trifluoroethenyl)borane, phenylbis(perfluorophenyl)bor-



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 30 5730

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. CL.5)
D, X	EP-A-0 418 044 (THE DOW CHEMICAL COMPANY) " claim 1 "	1-19	C08F10/00 C08F4/74
			TECHNICAL FIELDS SEARCHED (Int. CL.5)
			C08F
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 22 SEPTEMBER 1992	Examiner SERRAVALLE M.
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>Δ : member of the same patent family, corresponding document</p>			

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